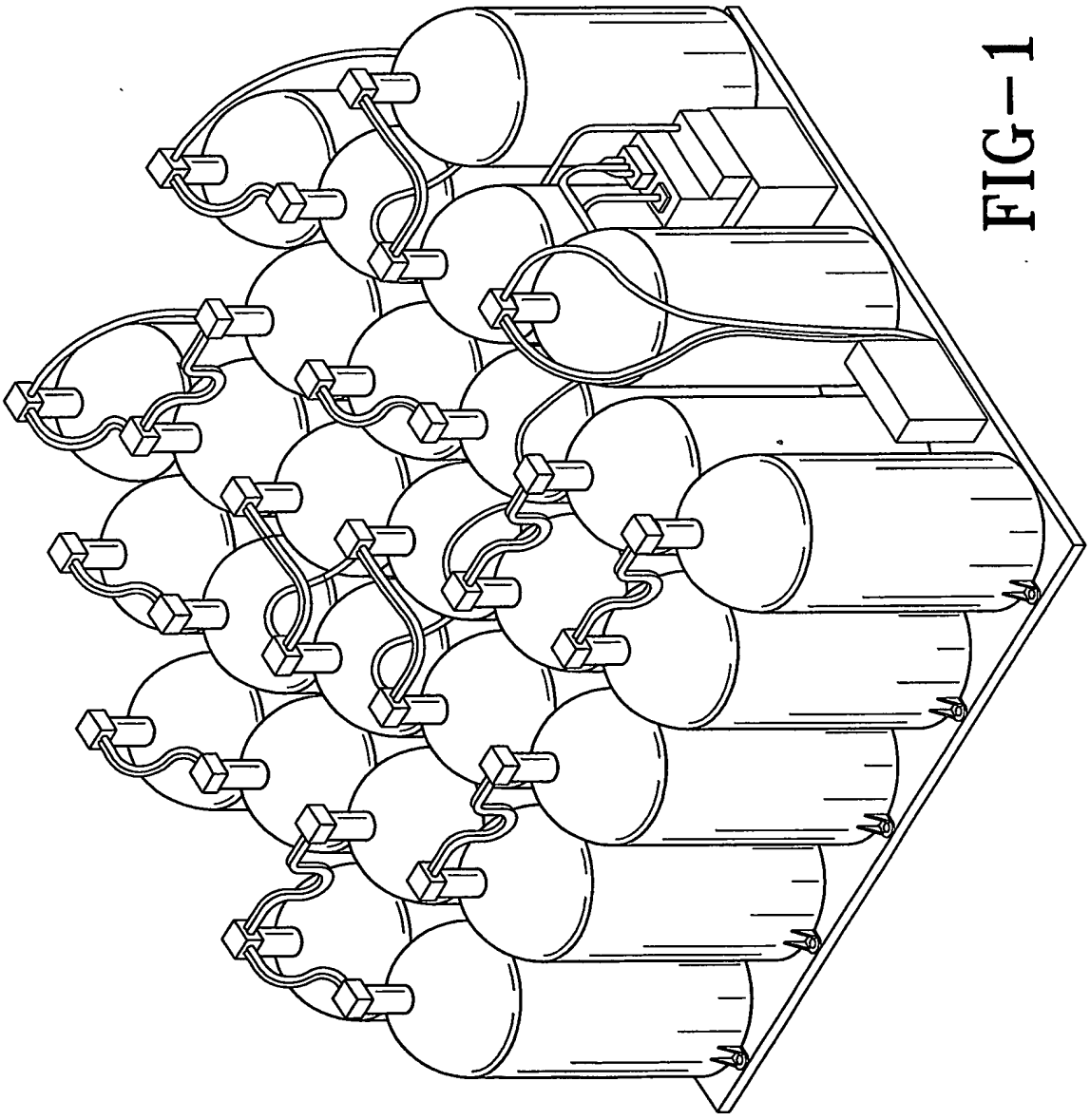


FIG-1

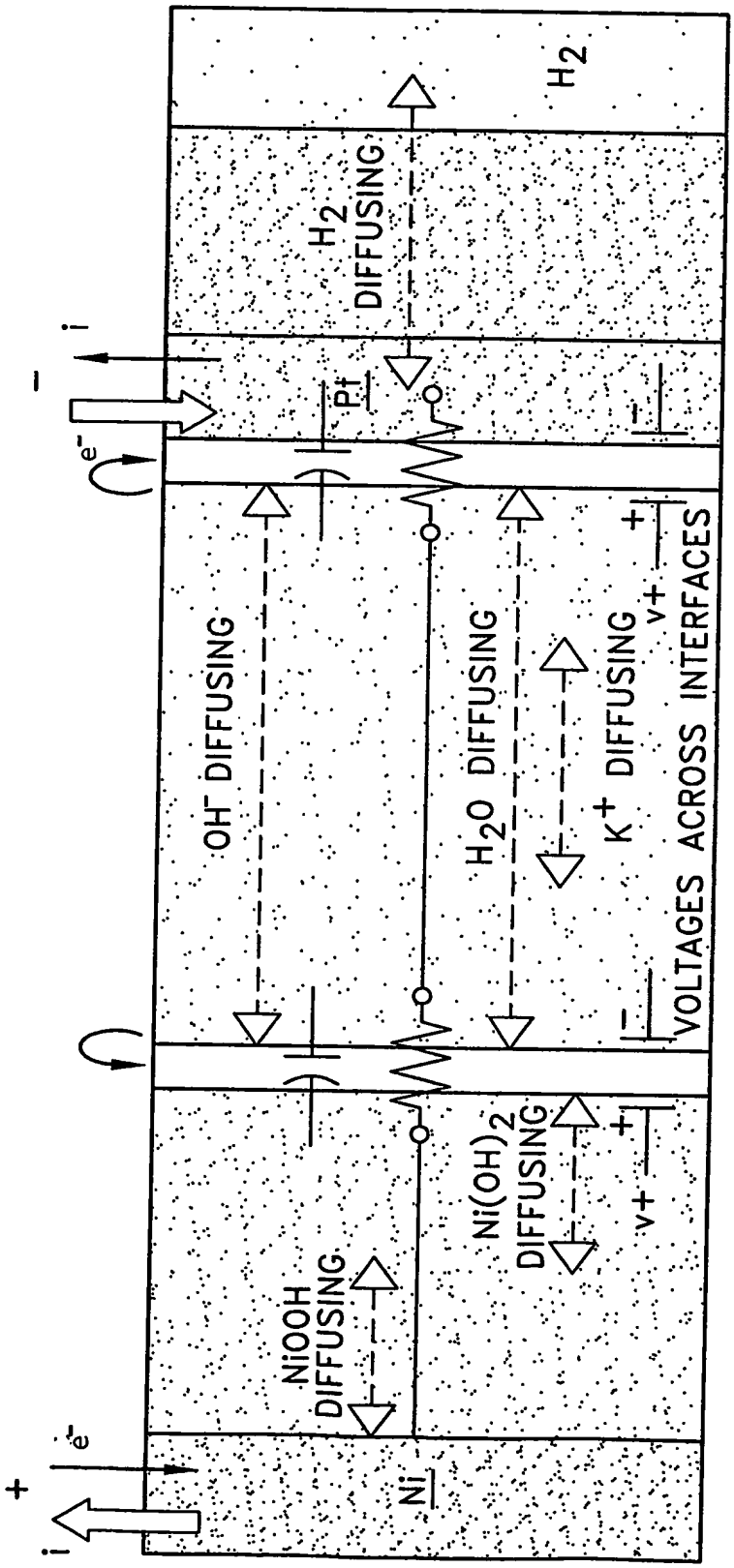
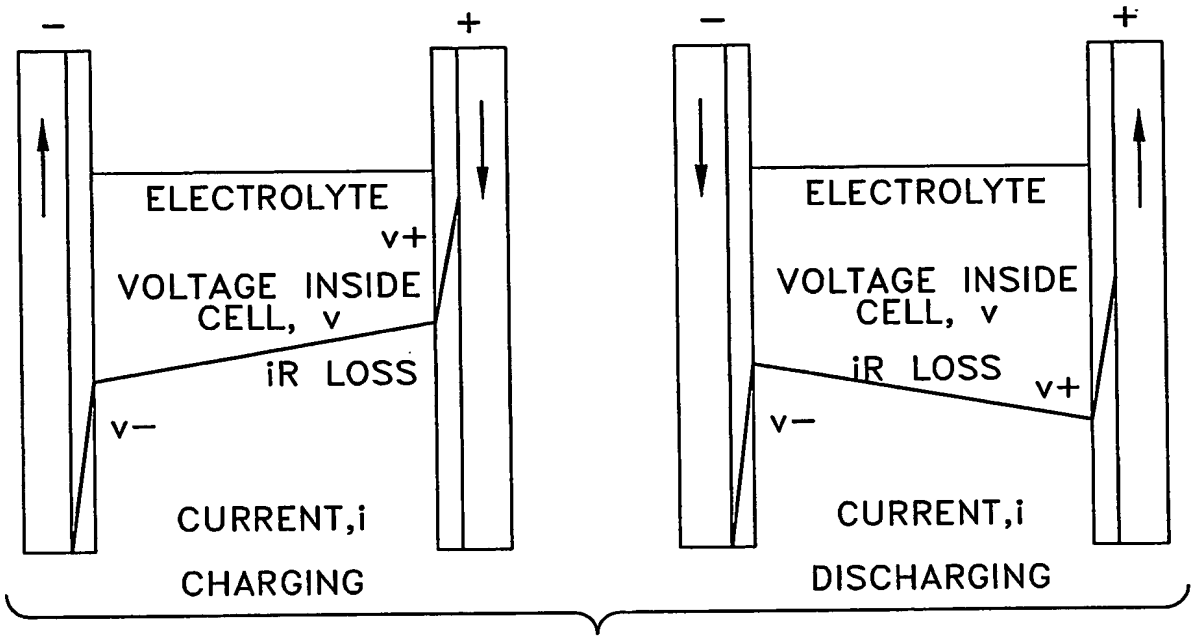
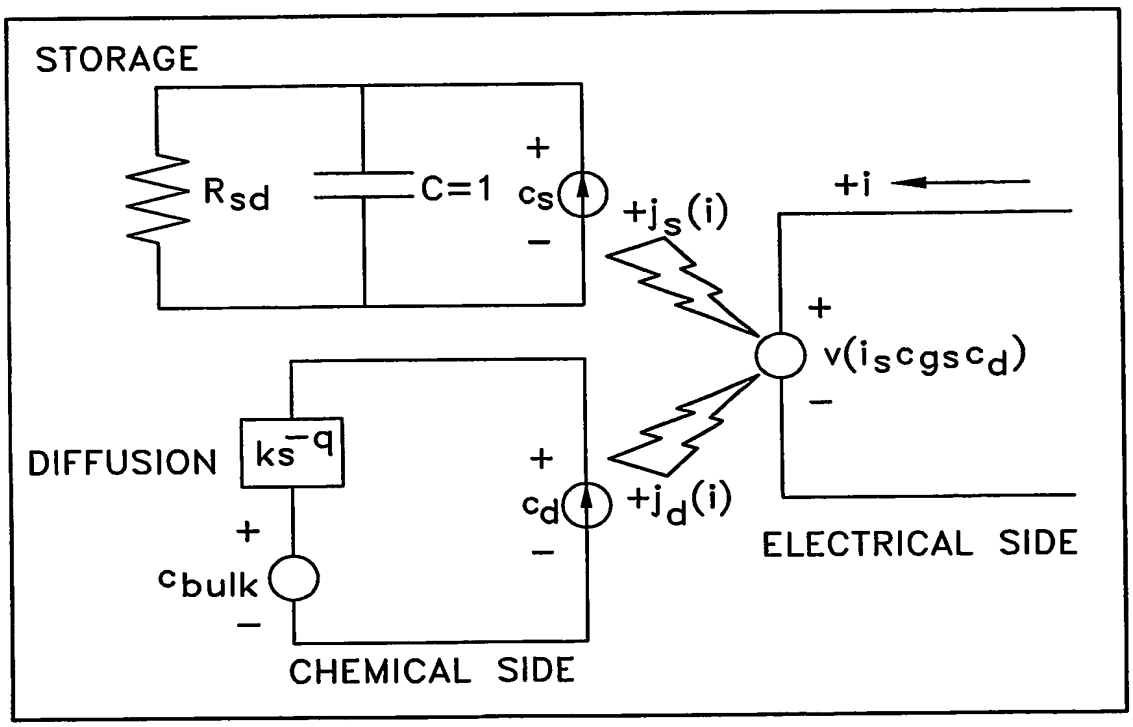

H_2
H_2 DIFFUSING
i
Pt
e^-
OH^- DIFFUSING
H_2O DIFFUSING
K^+ DIFFUSING
v+
VOLTAGES ACROSS INTERFACES
$Ni(OH)_2$ DIFFUSING
NiOOH DIFFUSING
Ni

FIG-2


−
+
ELECTROLYTE
v+
VOLTAGE INSIDE CELL, v
iR LOSS
v−
CURRENT,i
CHARGING
−
+
ELECTROLYTE
VOLTAGE INSIDE CELL, v
iR LOSS
v+
v−
CURRENT,i
DISCHARGING

FIG−3


STORAGE
Rsd
C=1
cs
+js(i)
+i
v(iscgscd)
DIFFUSION
ks−q
cd
+jd(i)
cbulk
ELECTRICAL SIDE
CHEMICAL SIDE

FIG−4

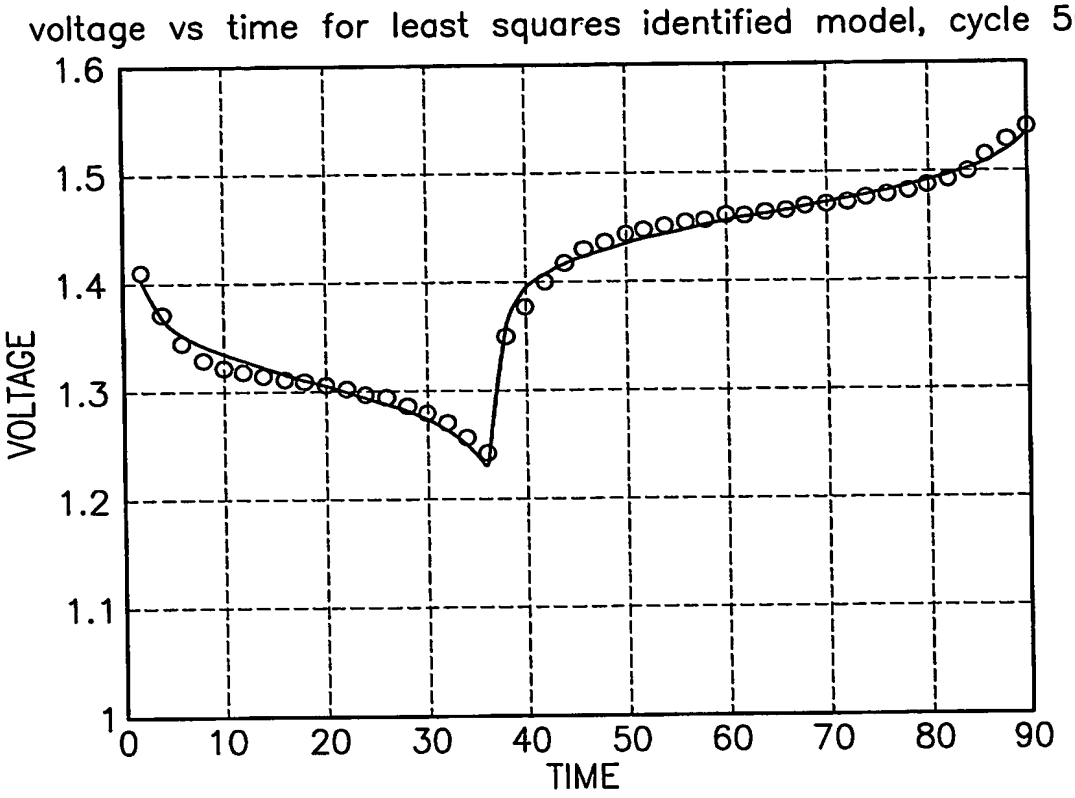

voltage vs time for least squares identified model, cycle 500
VOLTAGE
TIME
1.6
1.5
1.4
1.3
1.2
1.1
1
0
10
20
30
40
50
60
70
80
90

FIG-5

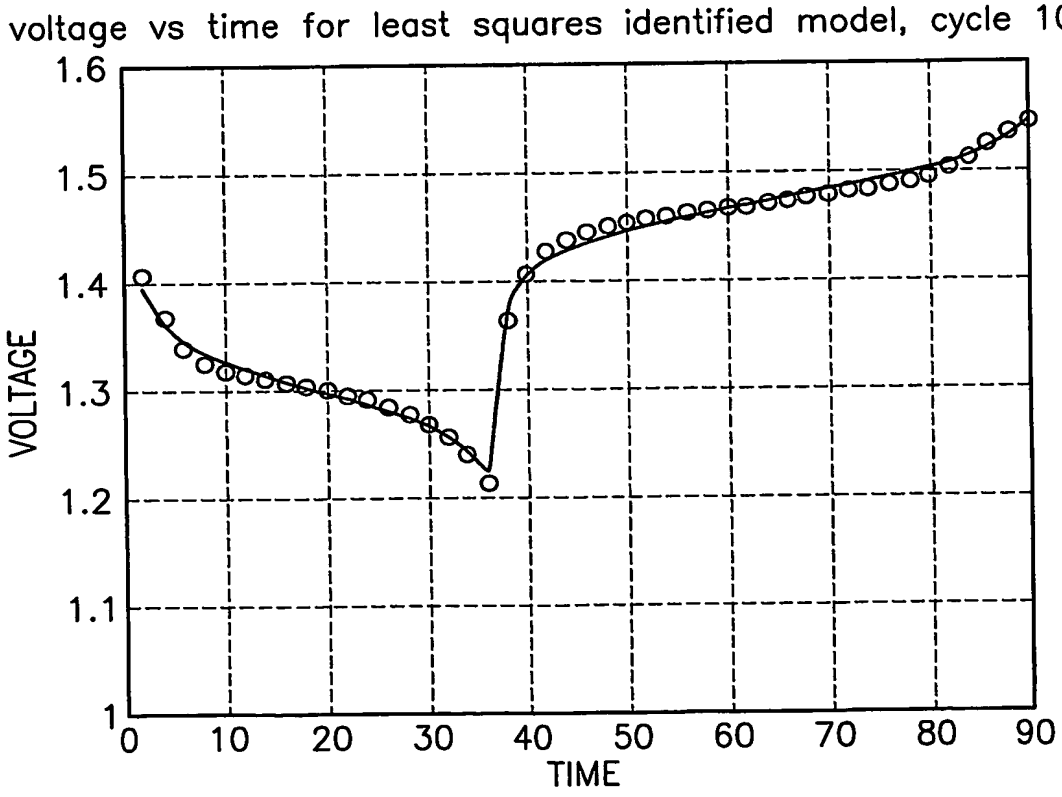
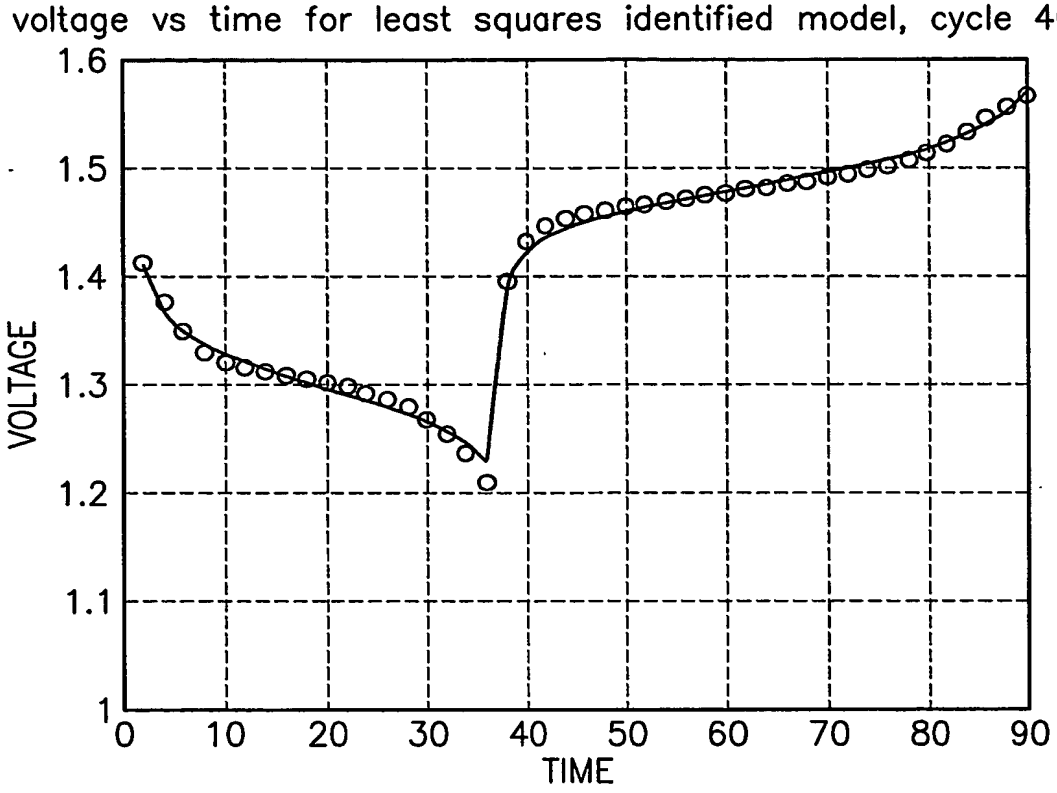
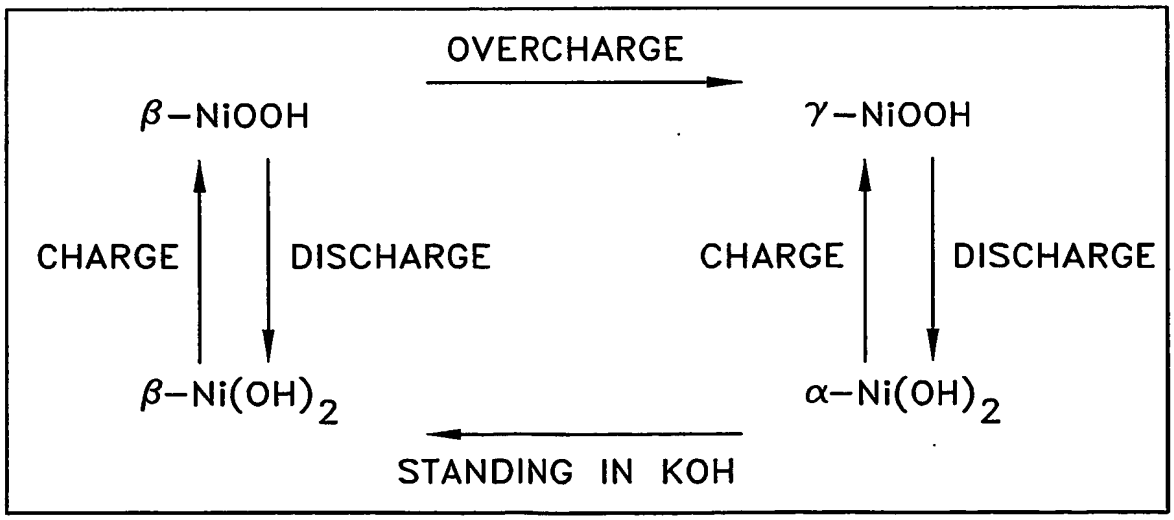

voltage vs time for least squares identified model, cycle 10000
VOLTAGE
TIME
1.6
1.5
1.4
1.3
1.2
1.1
1
0
10
20
30
40
50
60
70
80
90

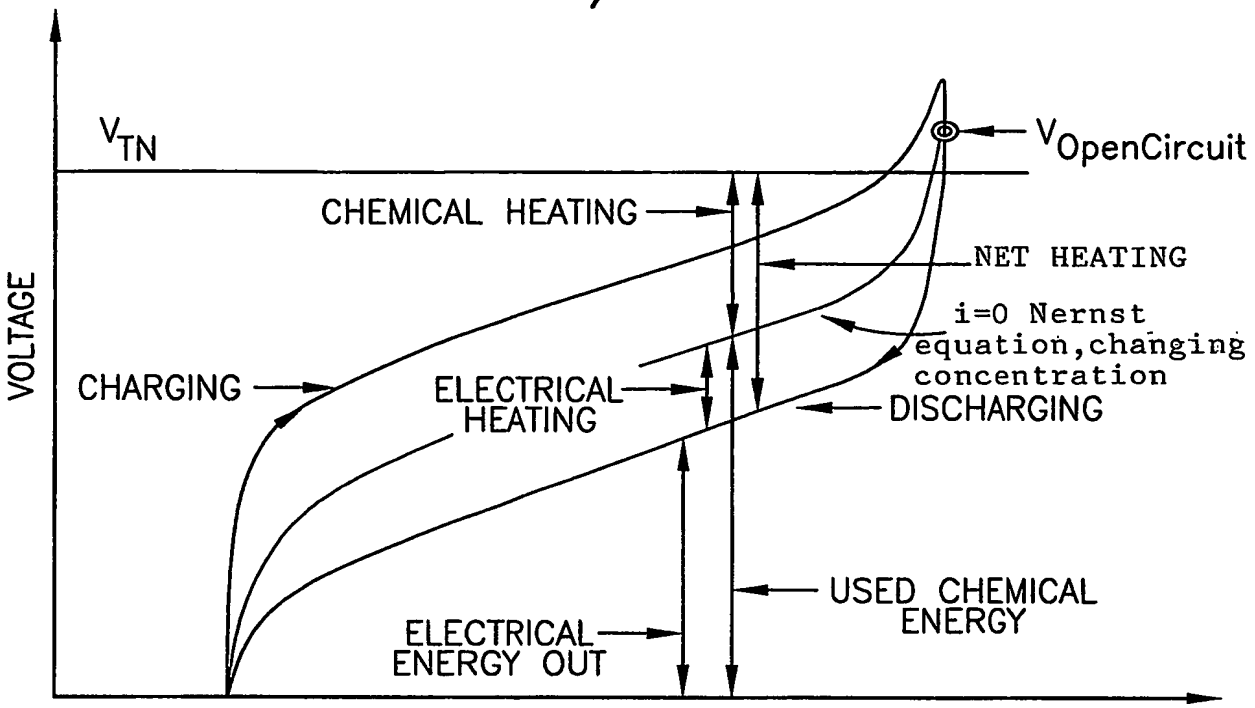
FIG-6


voltage vs time for least squares identified model, cycle 40000
VOLTAGE
TIME
1.6
1.5
1.4
1.3
1.2
1.1
1
0
10
20
30
40
50
60
70
80
90

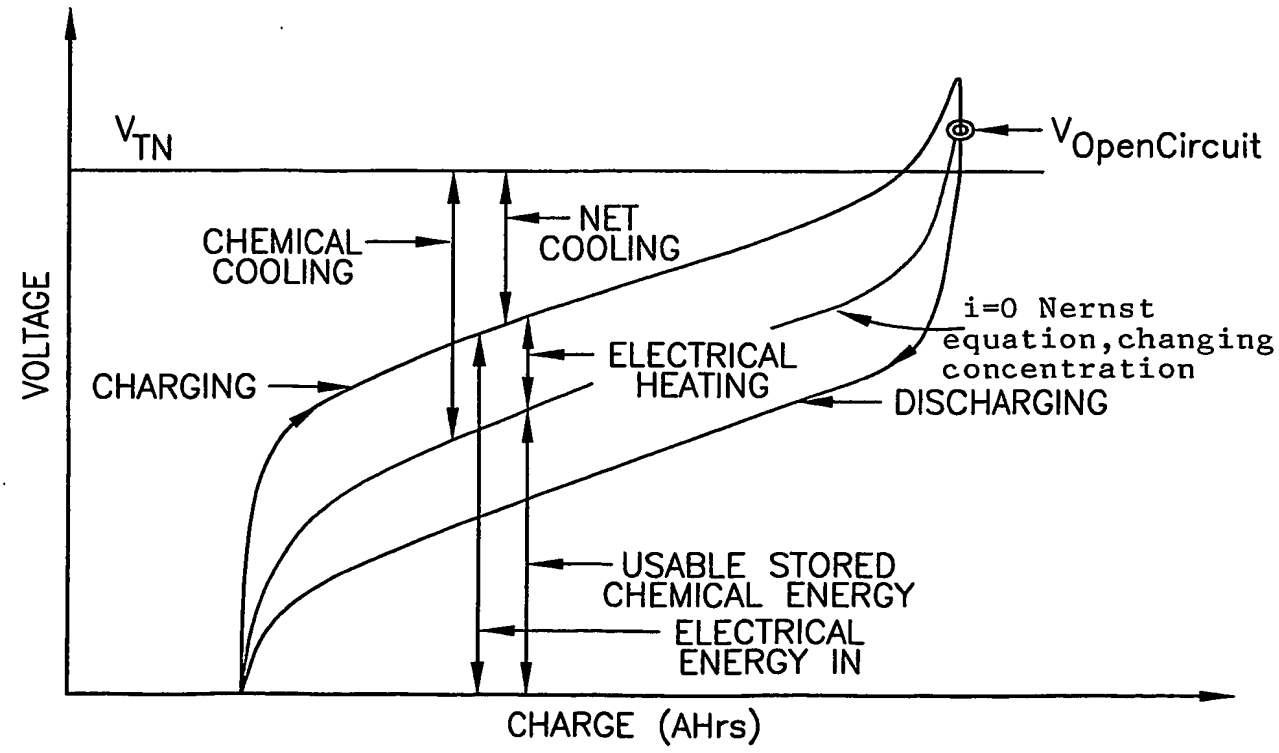
FIG–7


OVERCHARGE
β–NiOOH
γ–NiOOH
CHARGE
DISCHARGE
CHARGE
DISCHARGE
β–Ni(OH)2
α–Ni(OH)2
STANDING IN KOH

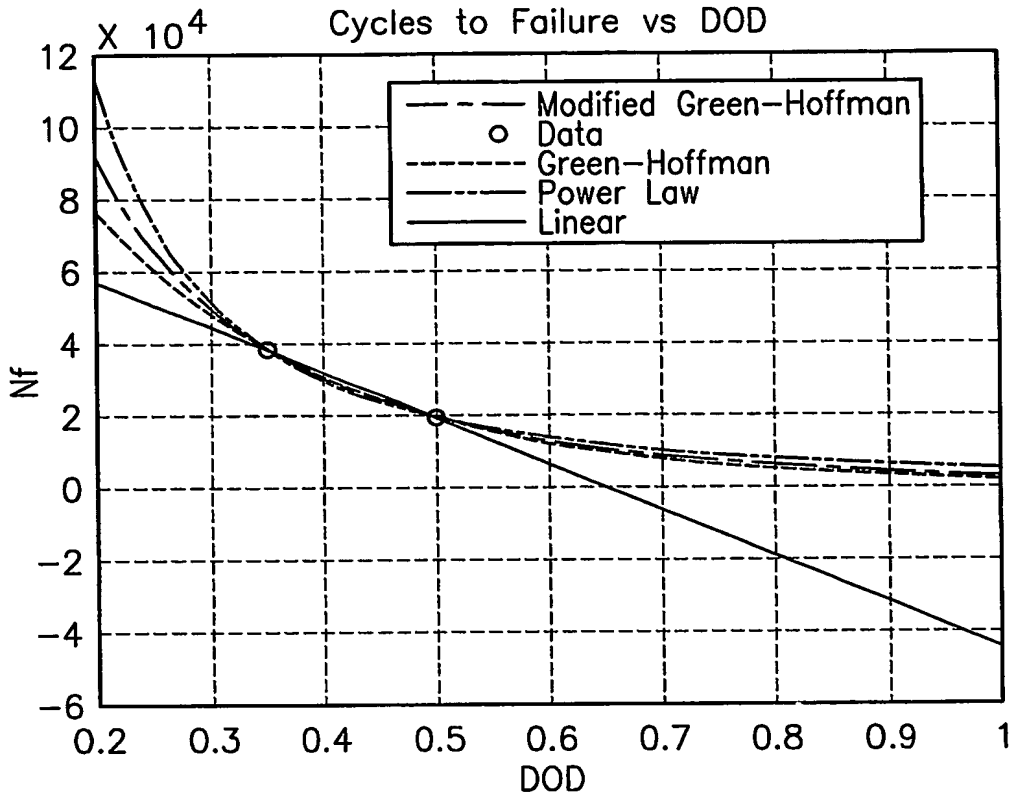
FIG–8


V_{TN}
$V_{OpenCircuit}$
CHEMICAL HEATING
NET HEATING
VOLTAGE
i=0 Nernst equation, changing concentration
CHARGING
ELECTRICAL HEATING
DISCHARGING
USED CHEMICAL ENERGY
ELECTRICAL ENERGY OUT

FIG–9


V_{TN}
$V_{OpenCircuit}$
CHEMICAL COOLING
NET COOLING
VOLTAGE
i=0 Nernst equation, changing concentration
ELECTRICAL HEATING
CHARGING
DISCHARGING
USABLE STORED CHEMICAL ENERGY
ELECTRICAL ENERGY IN
CHARGE (AHrs)

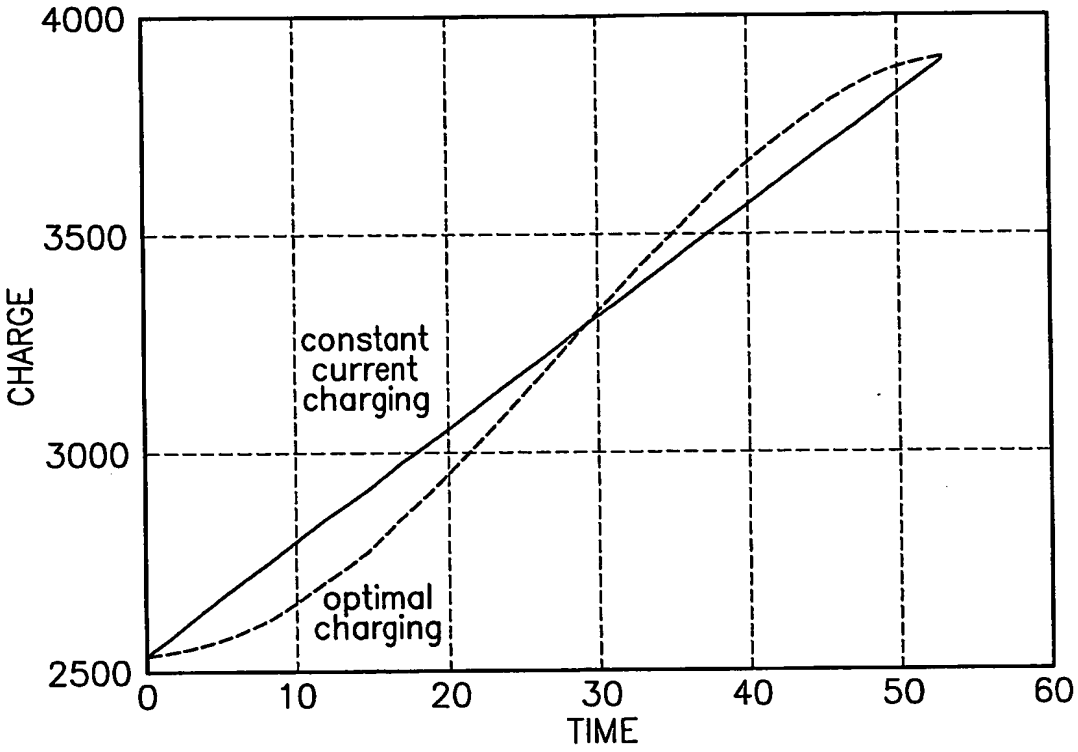
FIG–10



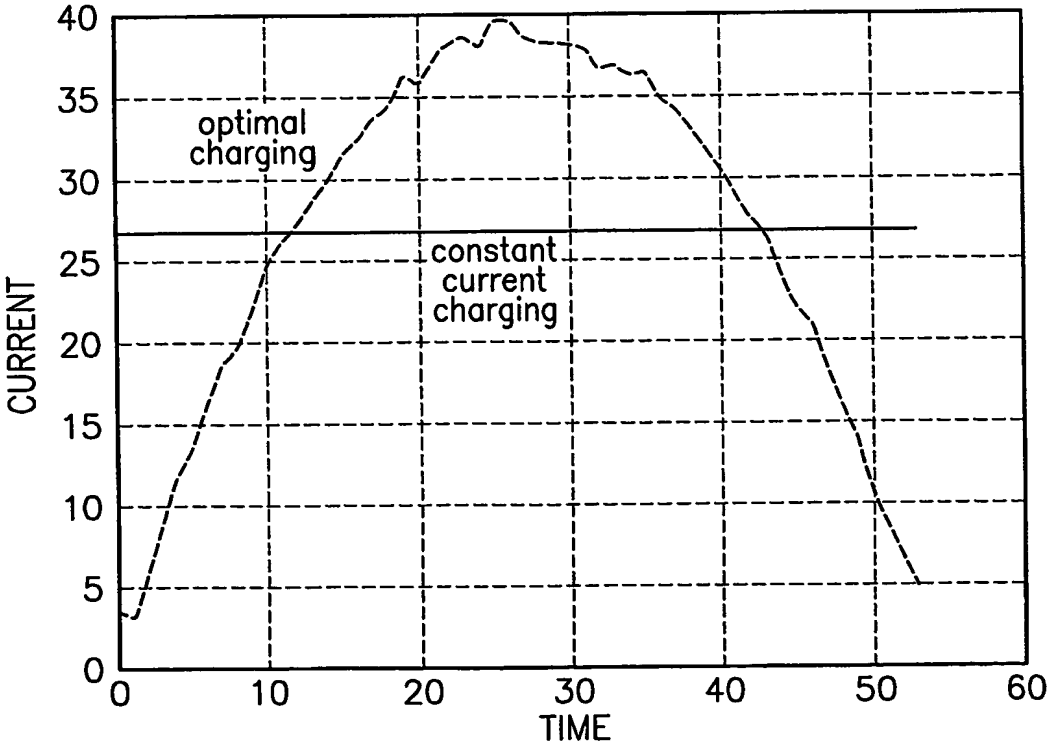
FIG−11

```
Load previous best
Set j=1
    Guess u(jT)
        Initialize simulation
                Main simulation loop
                        Derivative function evaluations
                        Numerical integration (Euler, T=1)
                        Damage rate calculation
                        Integrate damage rate
                End main loop
                Include final state error into Performance Measure
            Change u(jT) using gradient search and repeat until optimal
    Increment j and repeat
Reset j=1 and repeat until optimal
Store present best
```

FIG−12



FIG–13A



FIG–13B

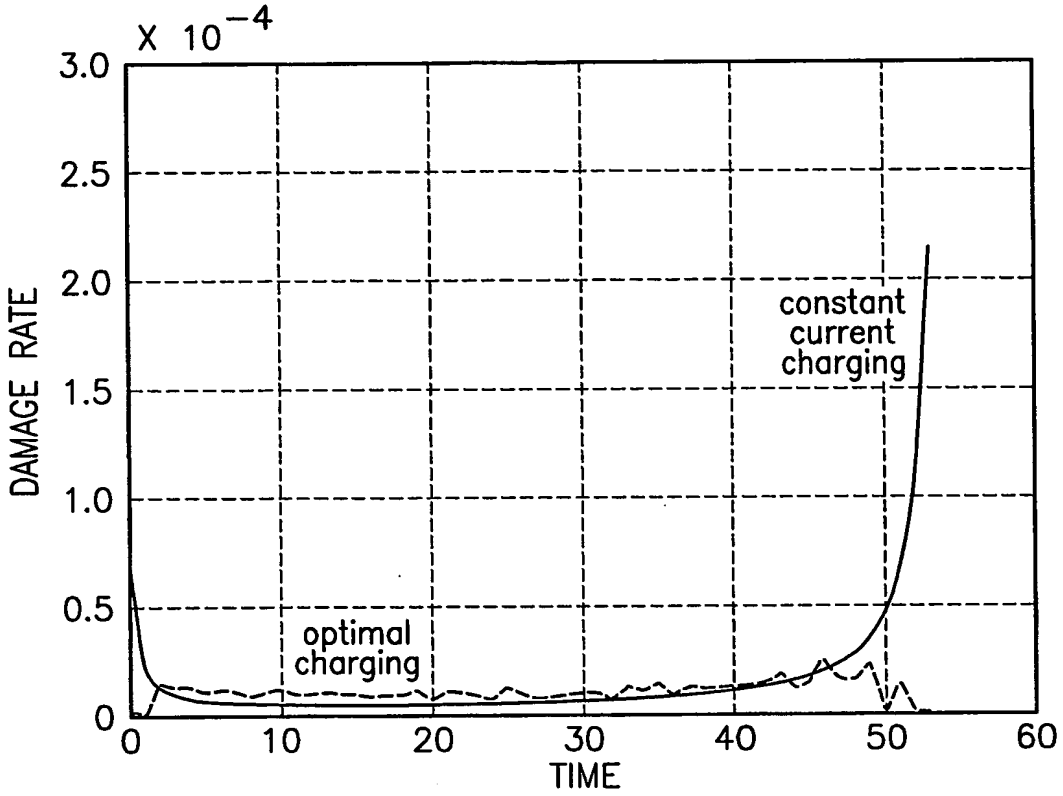


FIG-13C

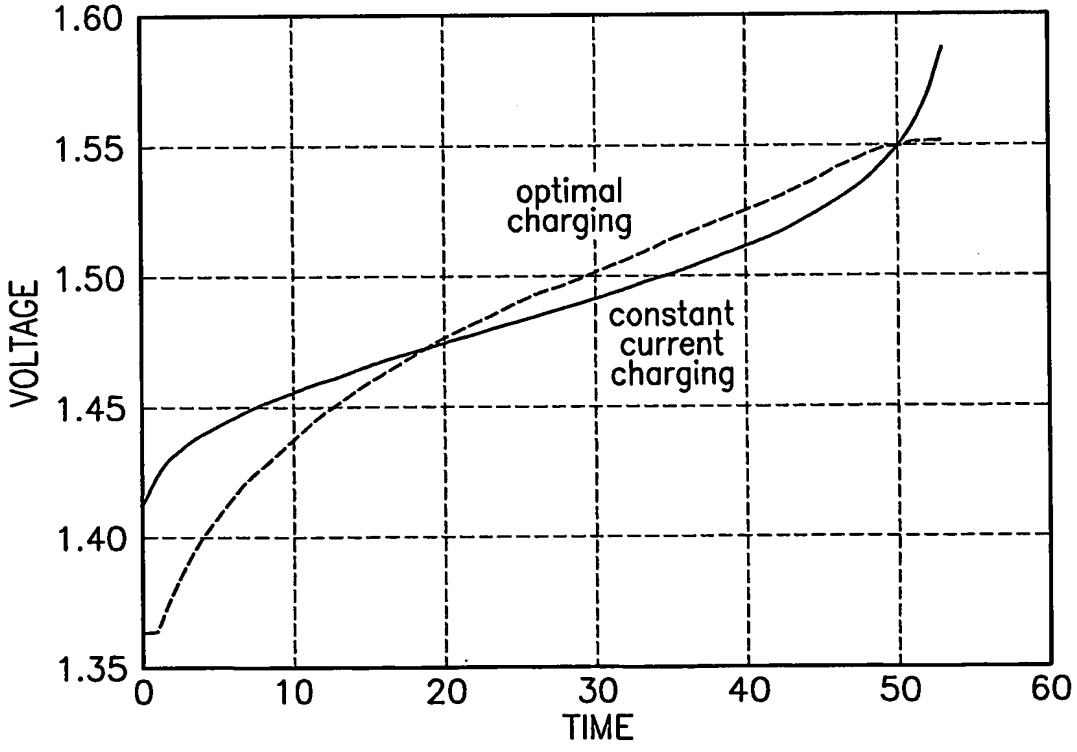


FIG-13D

```
Load previous best
    Guess u(t) function coefficients
    Initialize simulation
        Main simulation loop
                Derivative function evaluations
                Numerical integration (Euler, T=1)
                Damage rate calculation
                Integrate damage rate
        End main loop
        Include final state error into Performance Measure
  Change u(t) function coefficients using gradient search and repeat until optimal
Store present best
```

FIG-14

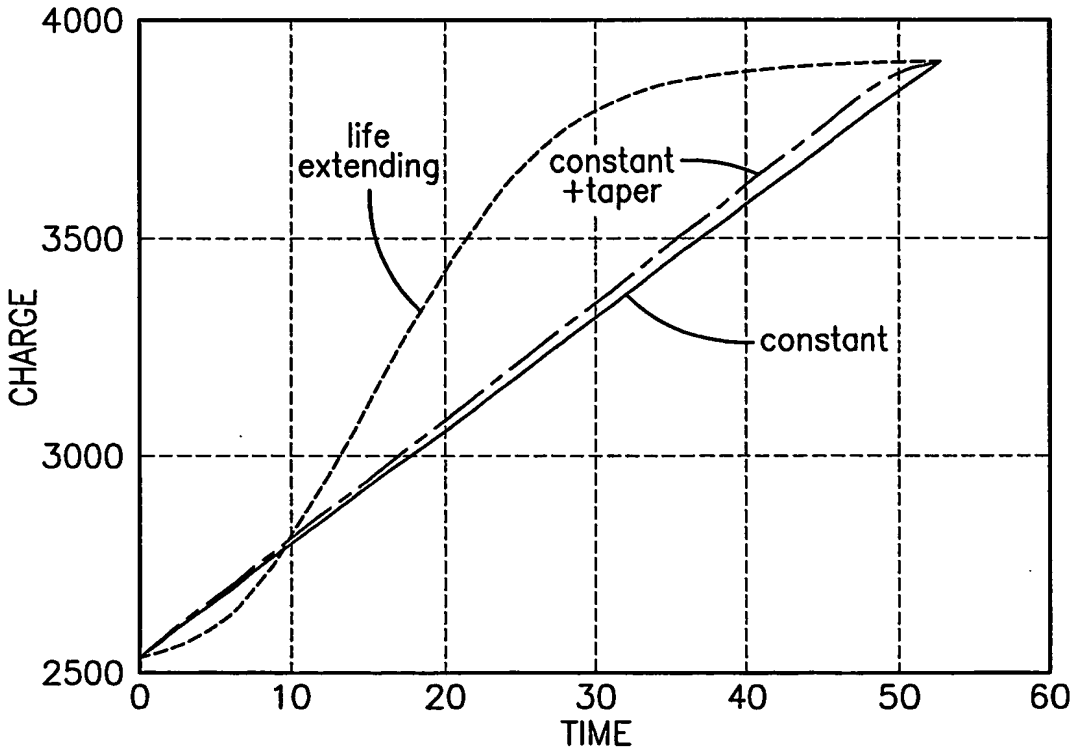


FIG-15A

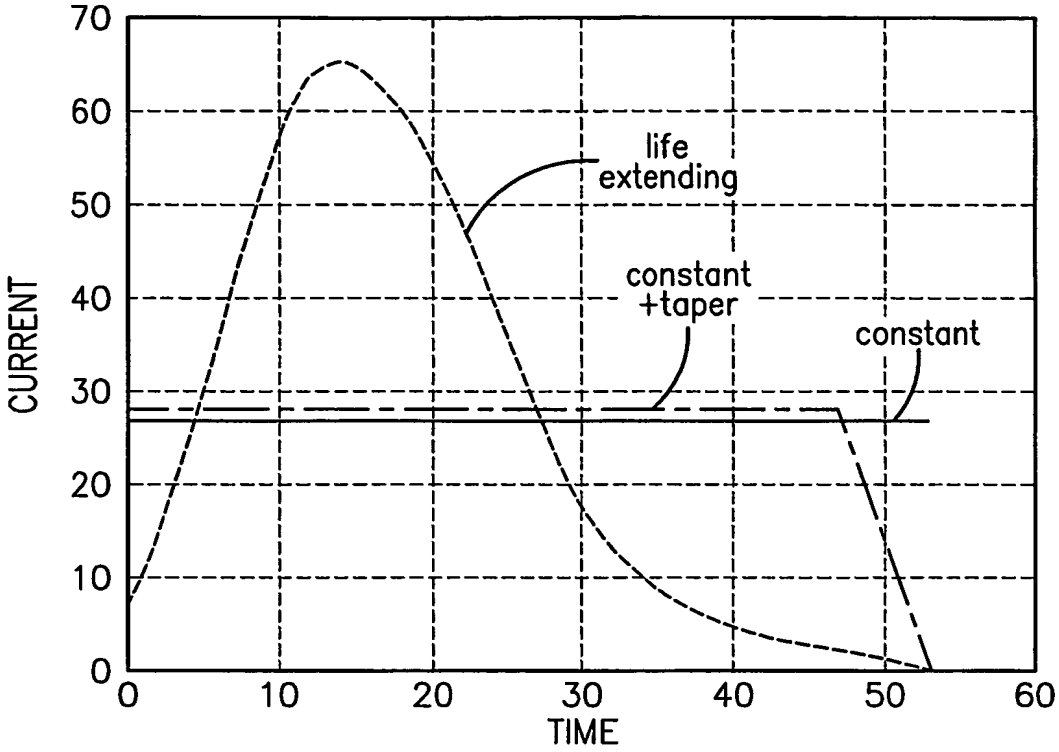


FIG-15B

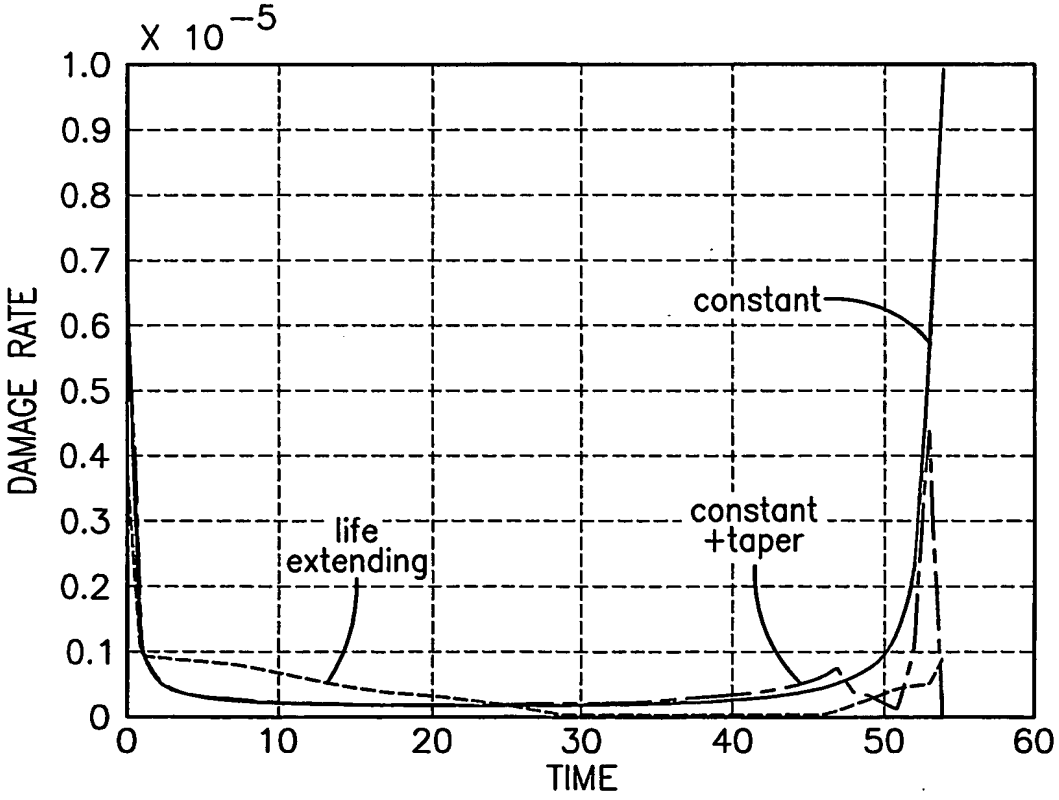


FIG-15C

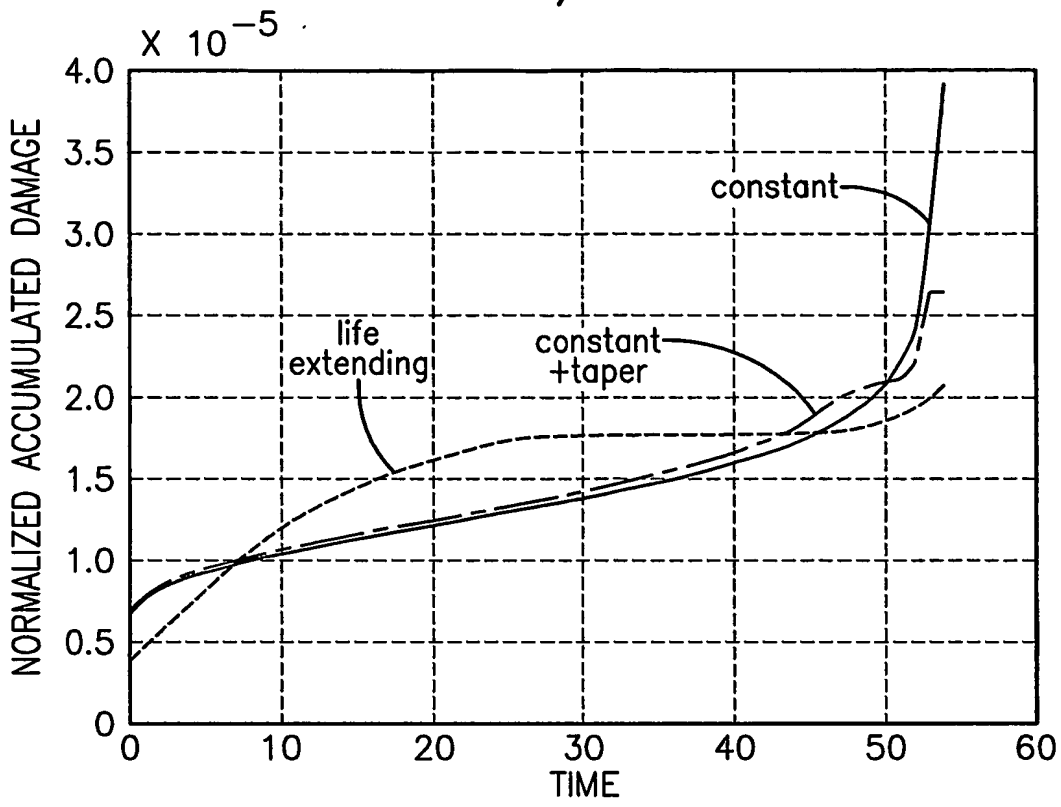


FIG-15D

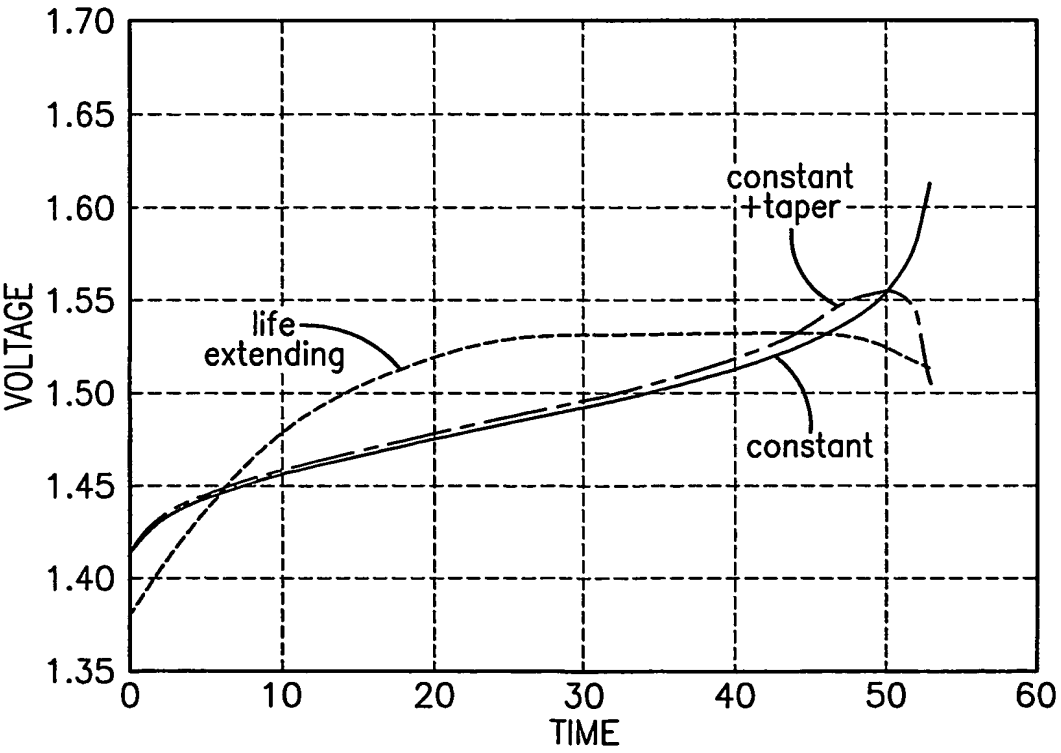
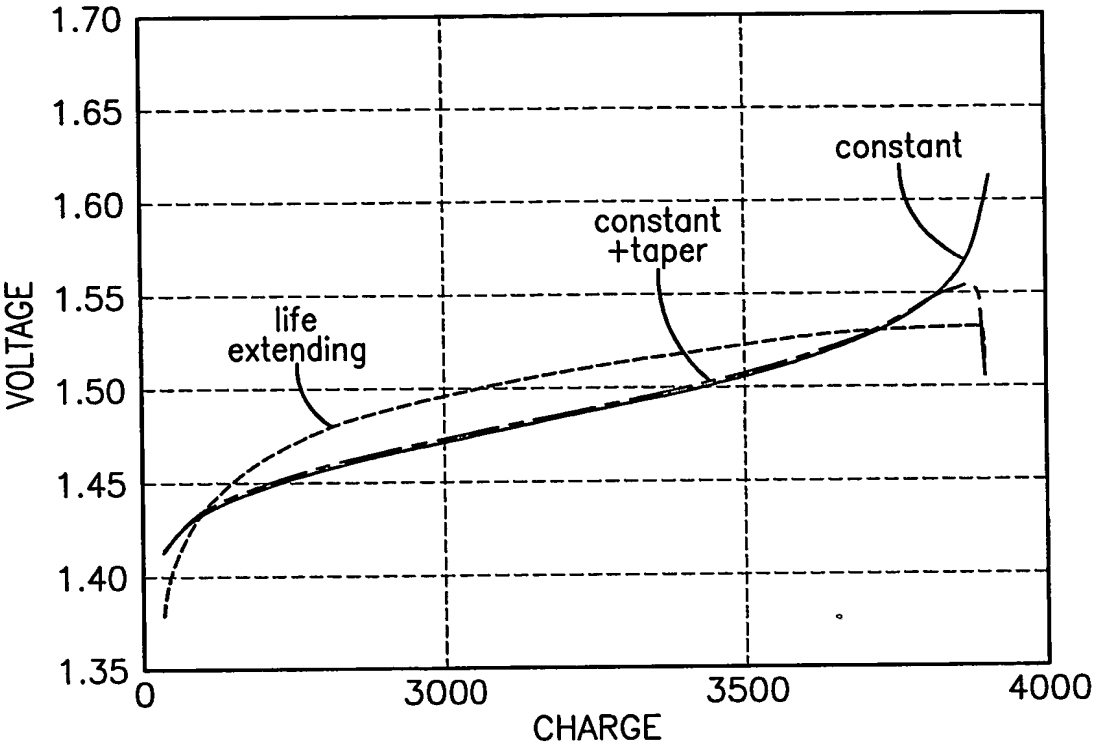
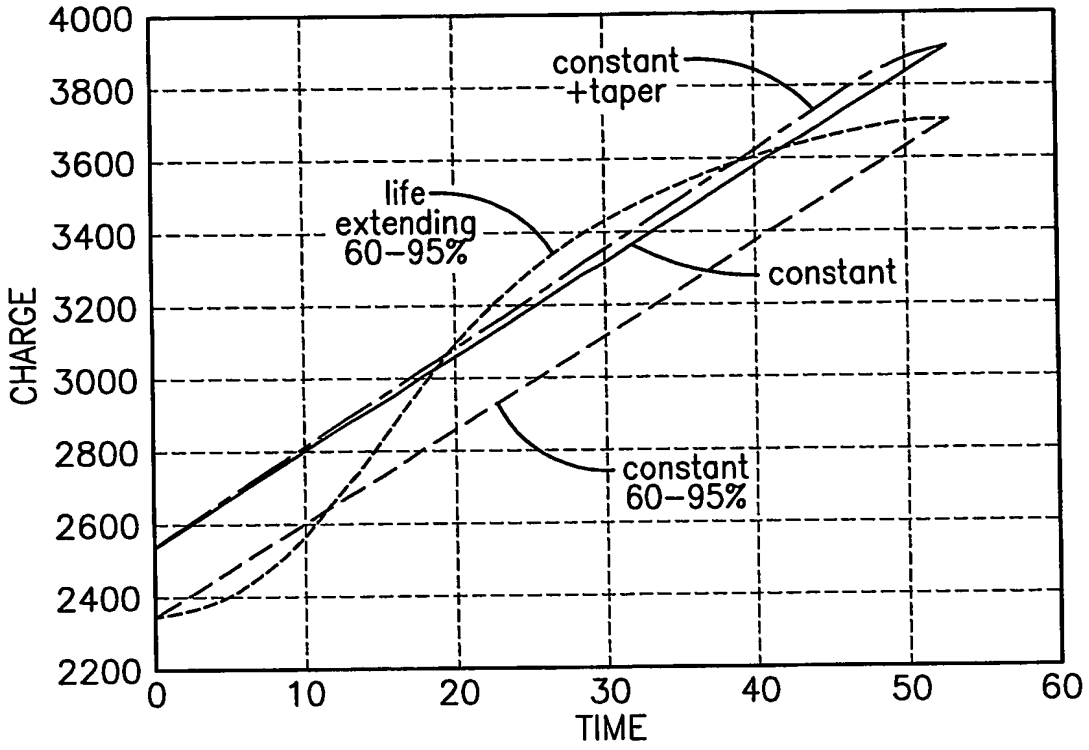


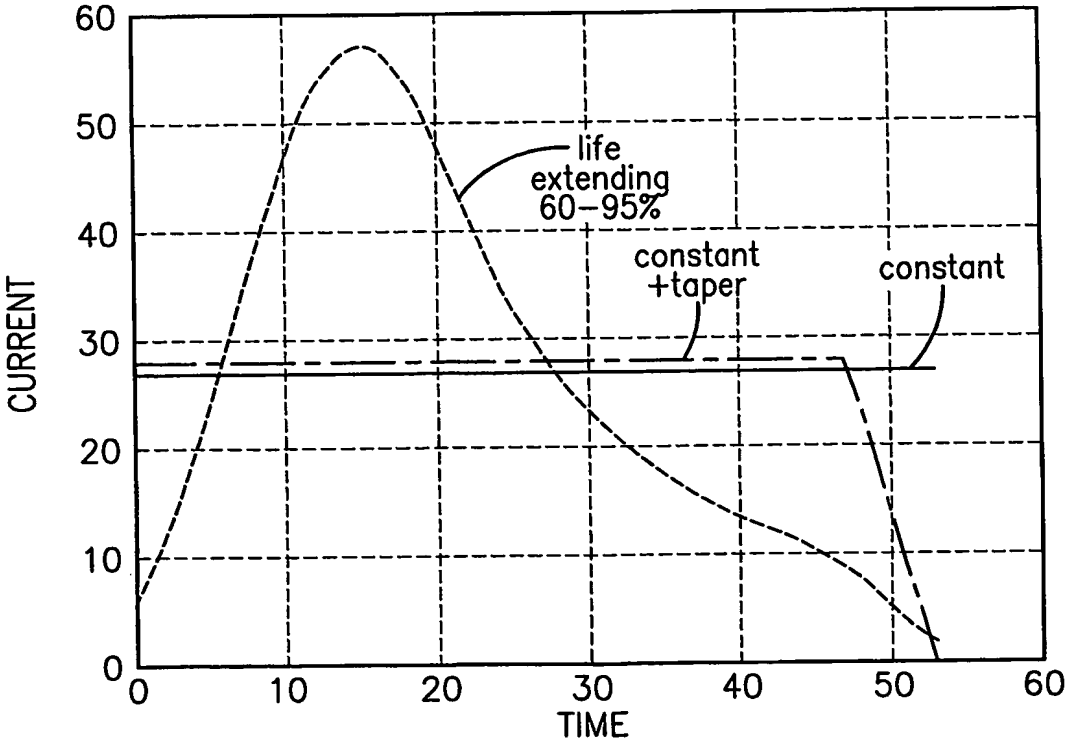
FIG-15E


1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
VOLTAGE
0
3000
3500
4000
CHARGE
constant
constant
+taper
life
extending

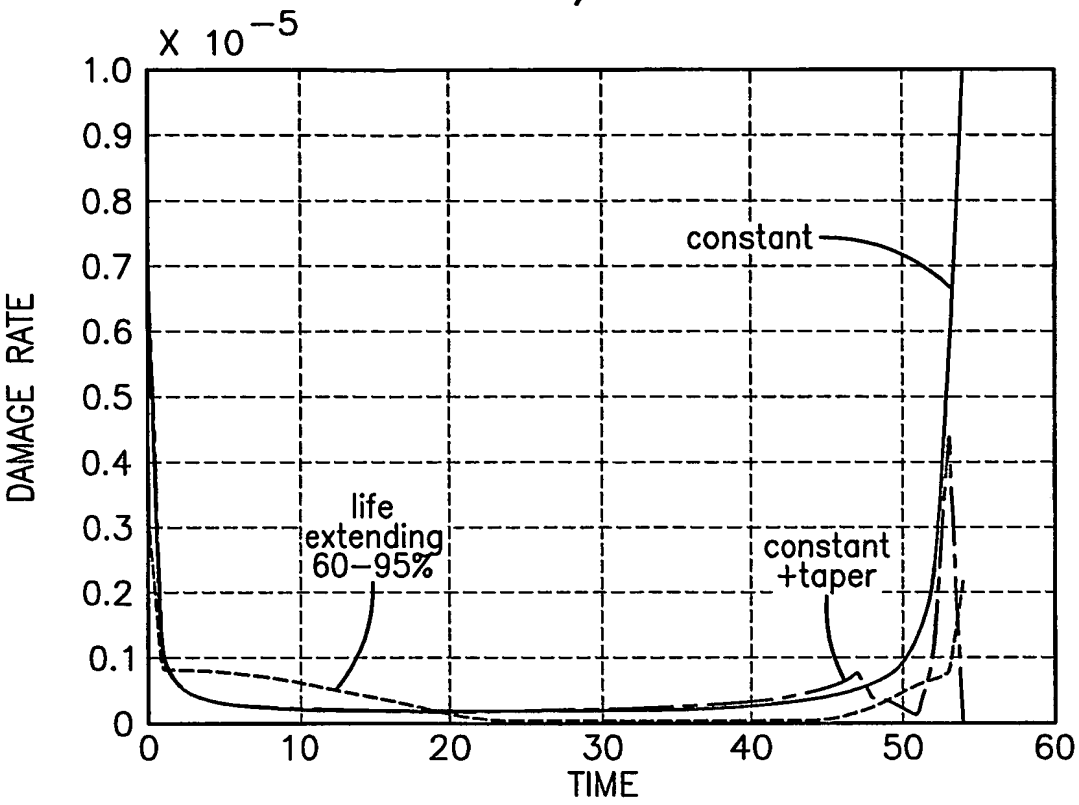
FIG–15F



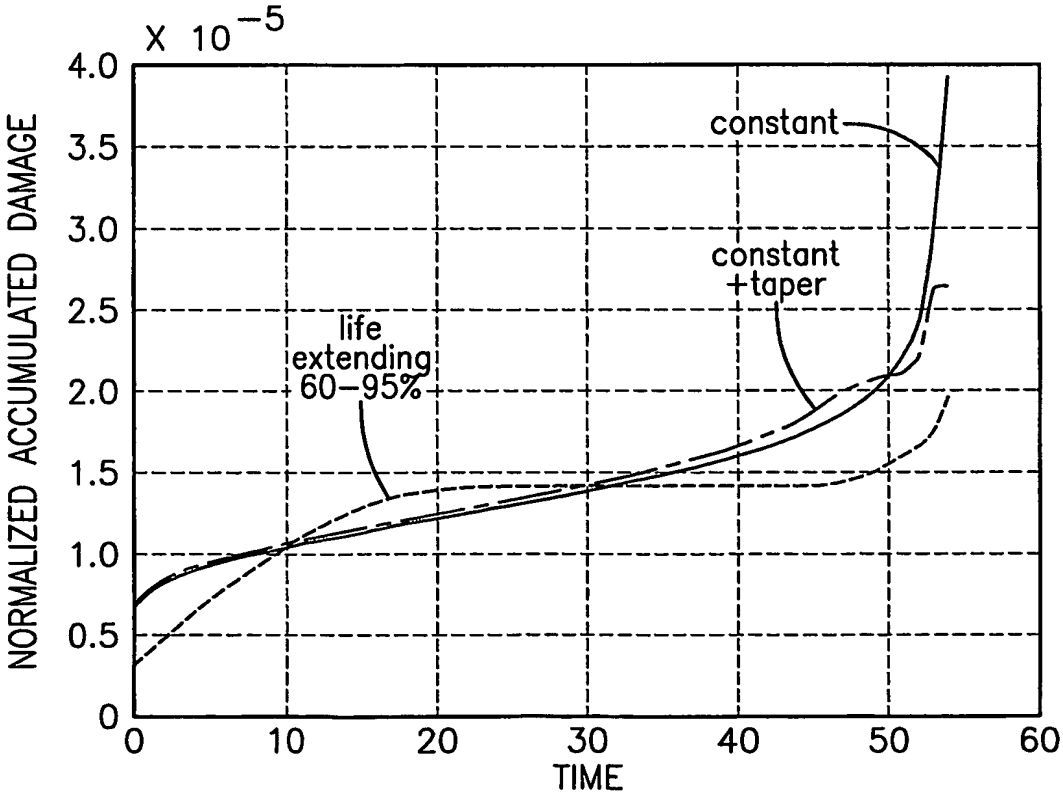
FIG–16A



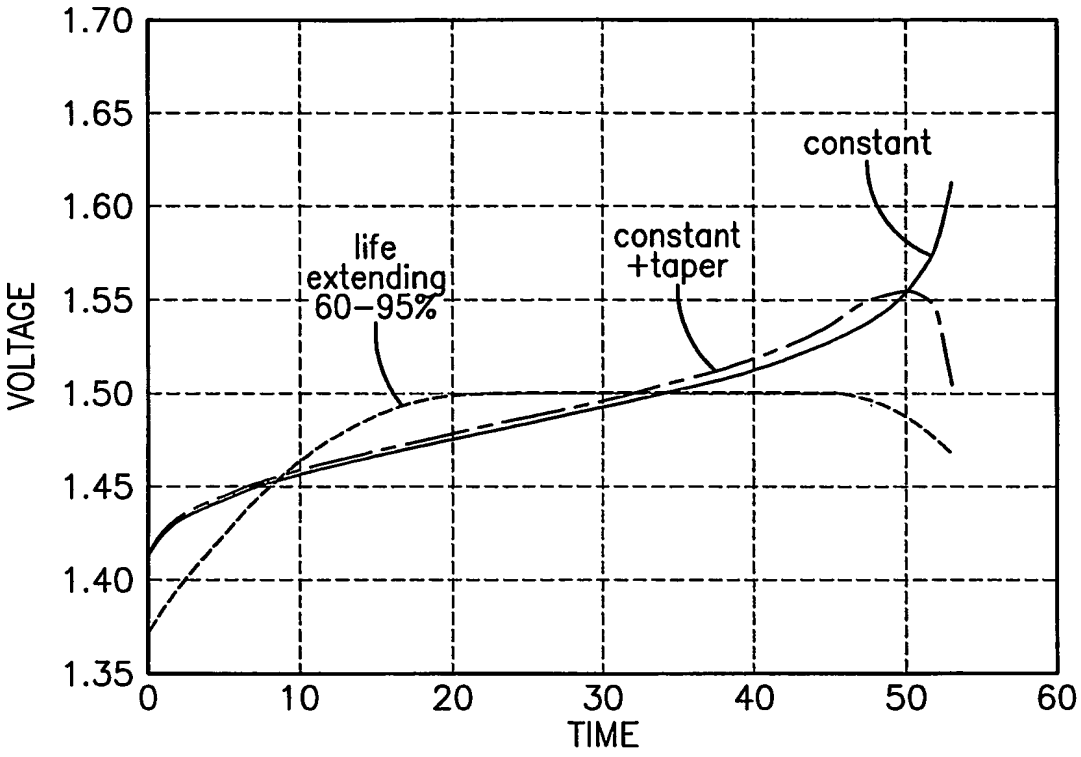
FIG–16B



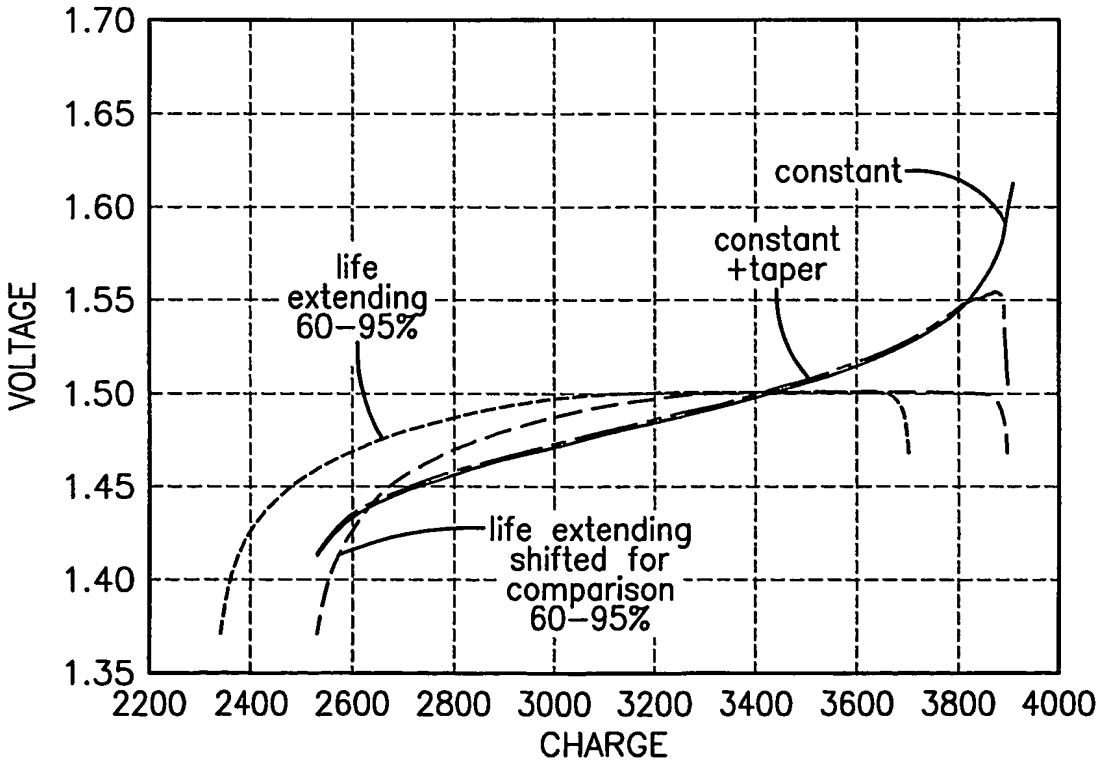
FIG–16C



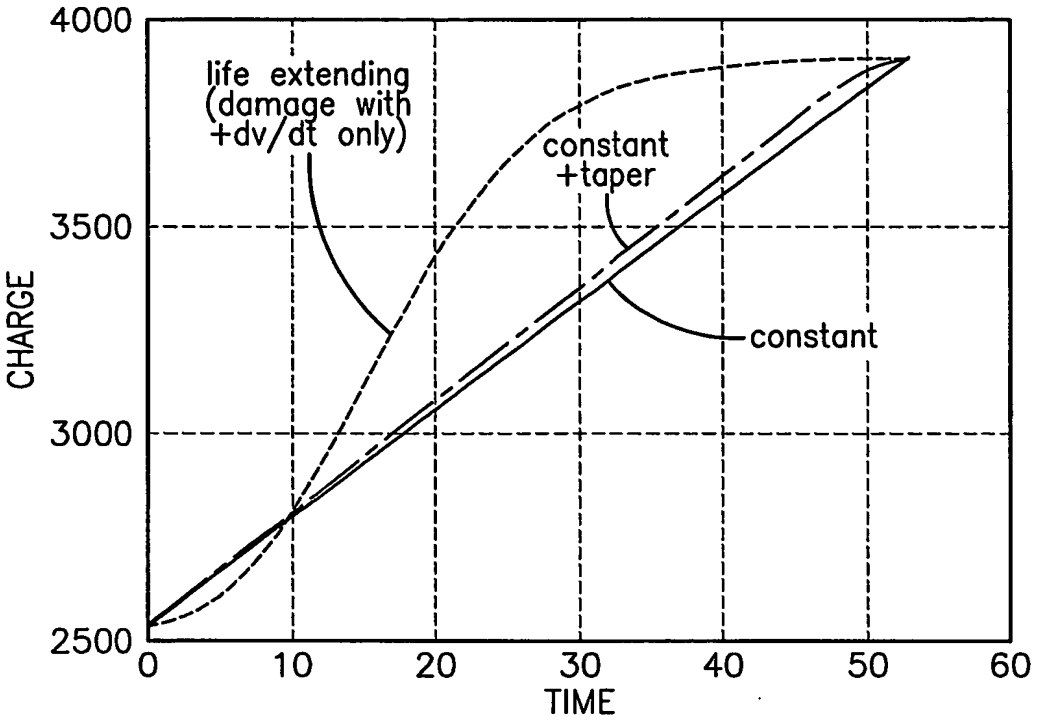
FIG–16D



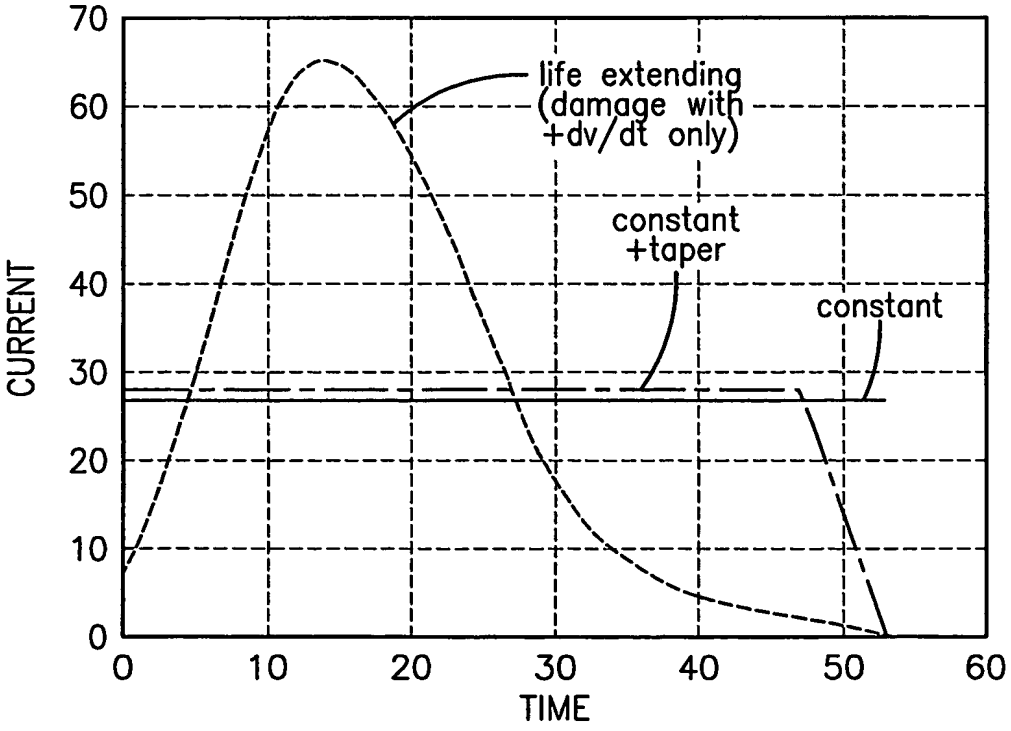
FIG–16E



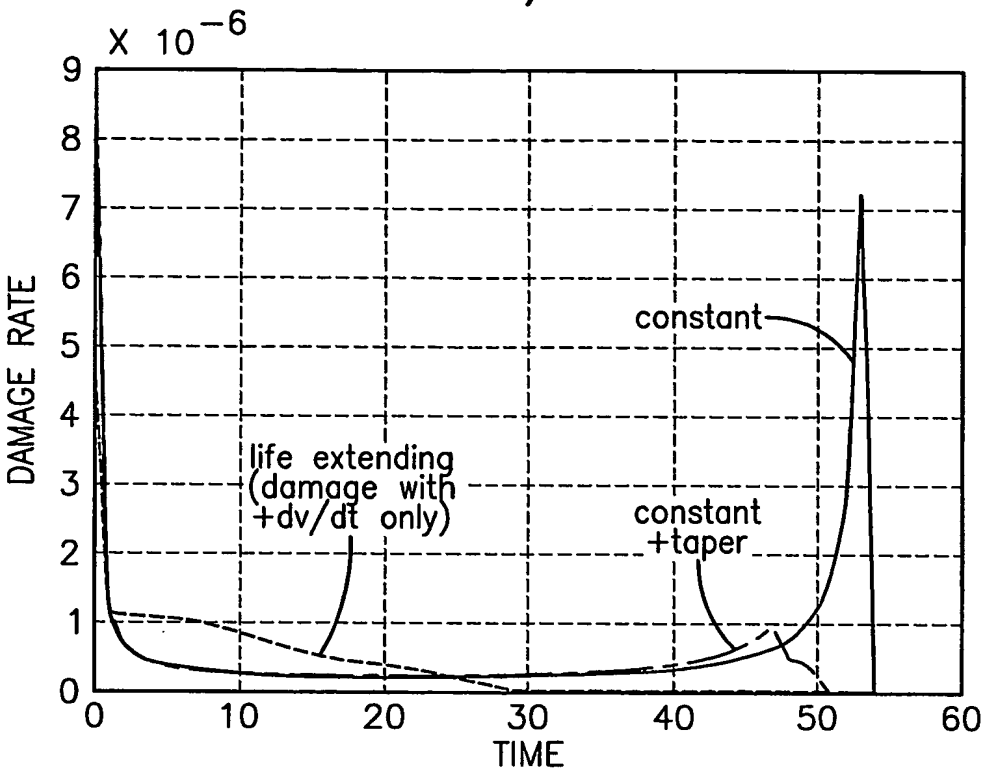
FIG–16F



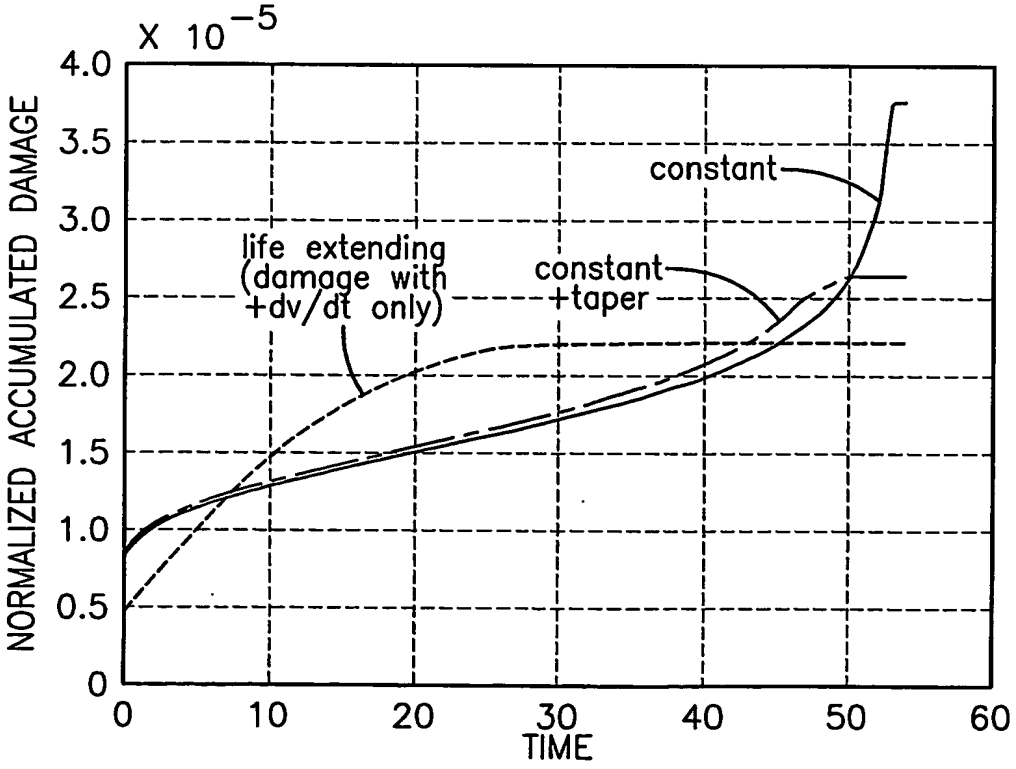
FIG–17A



FIG–17B



FIG–17C



FIG–17D

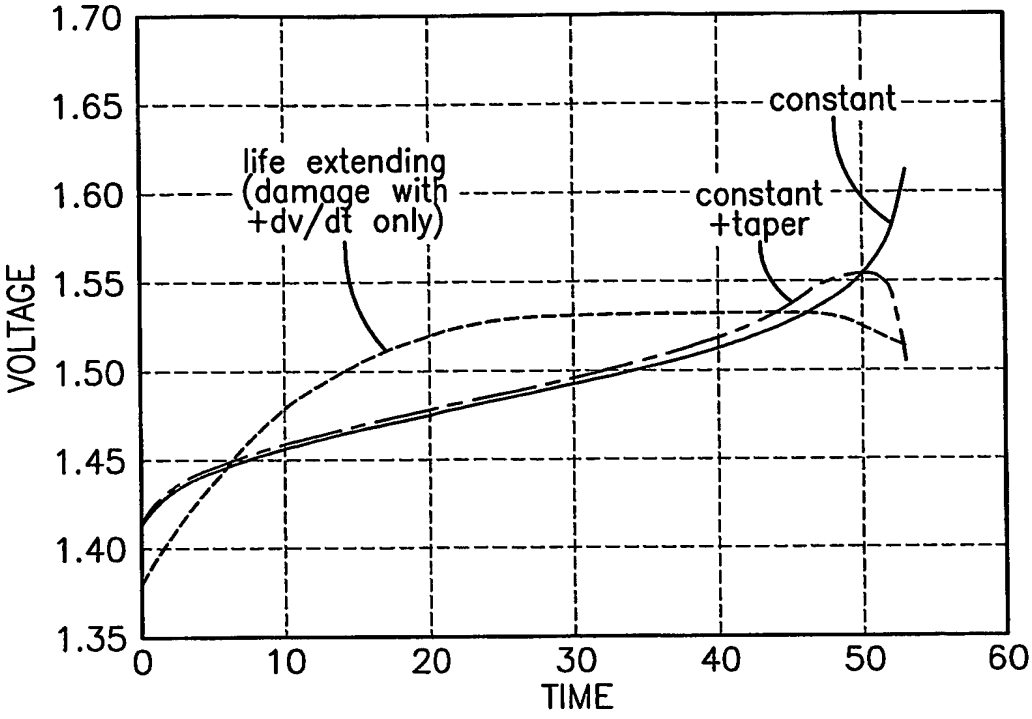


FIG-17E

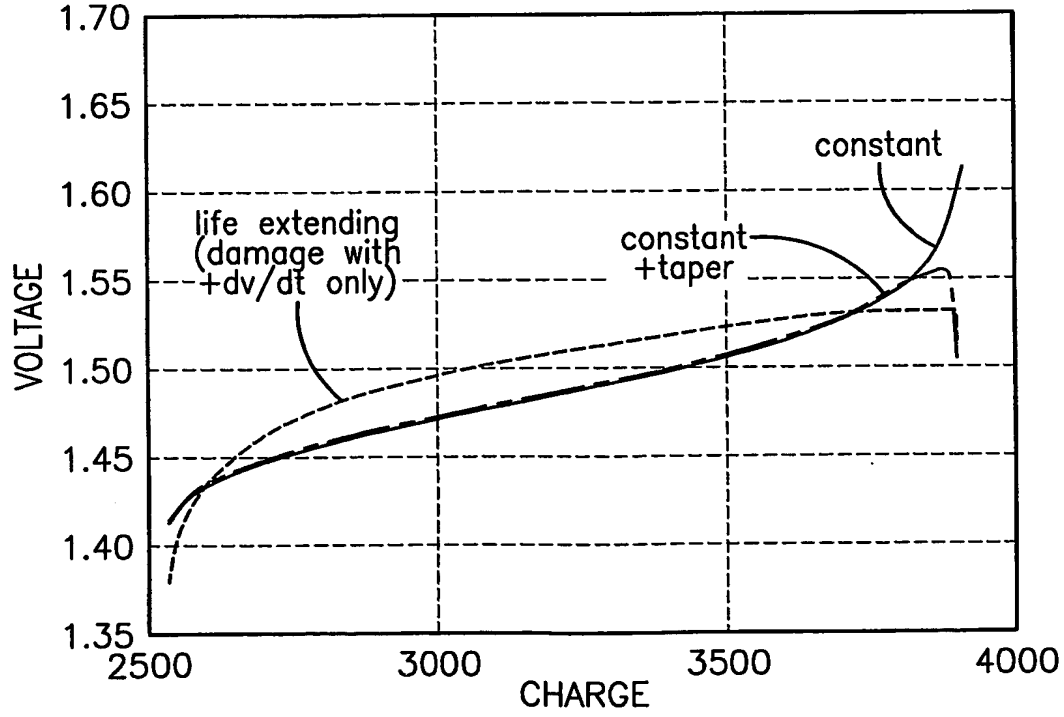


FIG-17F

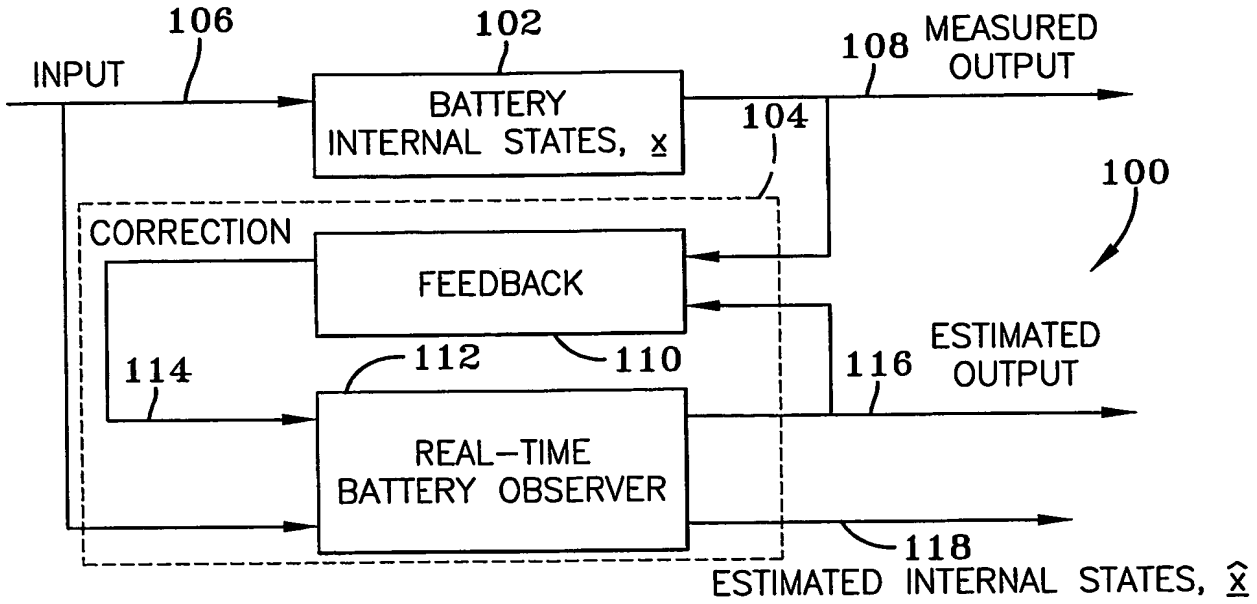

106
INPUT
102
BATTERY
INTERNAL STATES, x
108
MEASURED
OUTPUT
104
100
CORRECTION
FEEDBACK
114
112
110
116
ESTIMATED
OUTPUT
REAL-TIME
BATTERY OBSERVER
118
ESTIMATED INTERNAL STATES, x̂

FIG-18

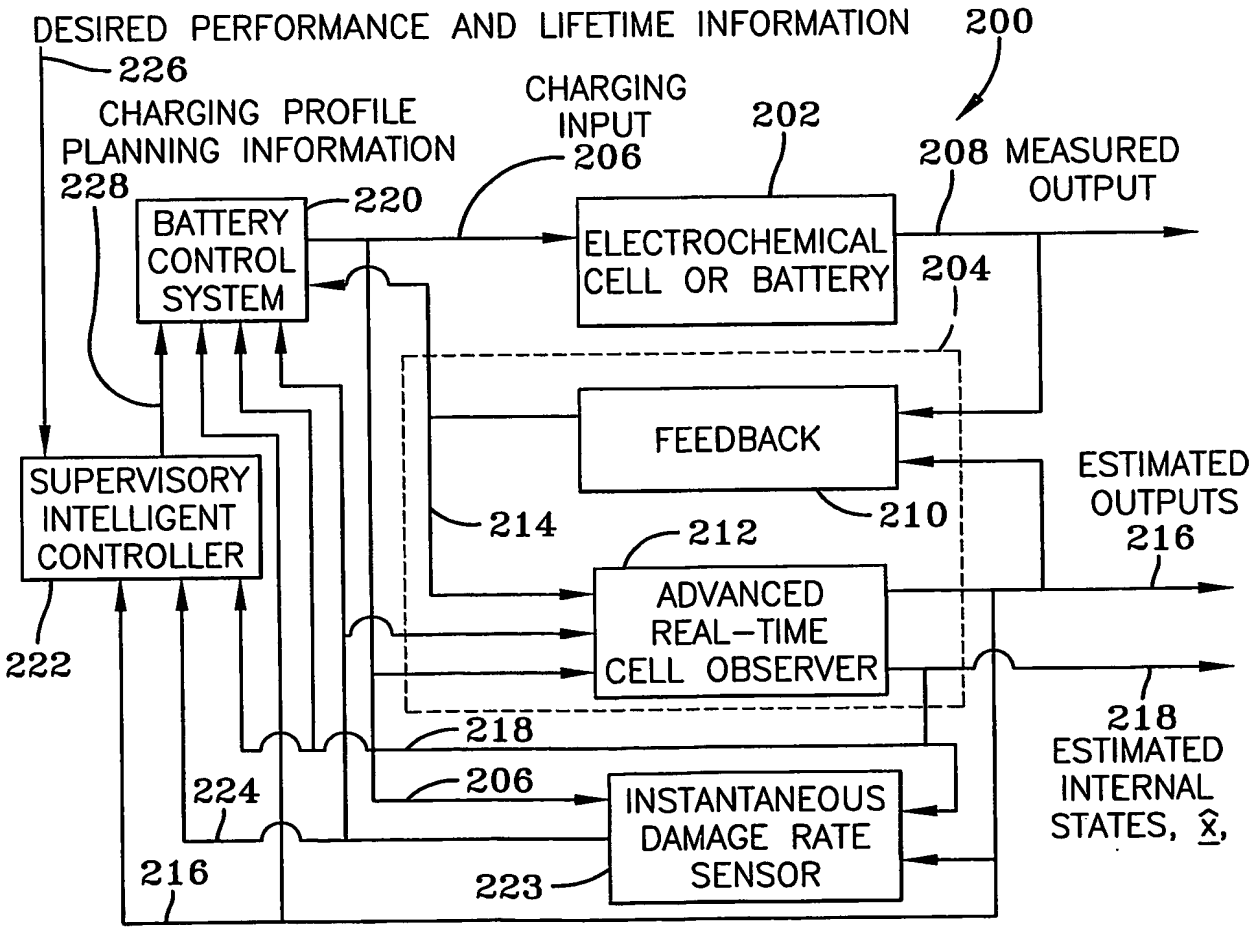

DESIRED PERFORMANCE AND LIFETIME INFORMATION
200
226
CHARGING PROFILE
PLANNING INFORMATION
228
CHARGING
INPUT
206
202
208 MEASURED
OUTPUT
220
BATTERY
CONTROL
SYSTEM
ELECTROCHEMICAL
CELL OR BATTERY
204
FEEDBACK
ESTIMATED
OUTPUTS
216
SUPERVISORY
INTELLIGENT
CONTROLLER
214
212
210
ADVANCED
REAL-TIME
CELL OBSERVER
222
218
218
ESTIMATED
INTERNAL
STATES, x̂,
206
224
INSTANTANEOUS
DAMAGE RATE
SENSOR
216
223

FIG-19